

*Citation for published version:*

Davenport, J, Fleuriot, J, Quaresma, P, Recio, T & Wang, D 2019, Intelligent Geometry Tools. in *Proceedings of the Second International Workshop on Automated Reasoning: Challenges, Applications, Directions, Exemplary Achievements (ARCADE)*. Electronic Proceedings in Theoretical Computer Science, vol. 311, EasyChair Publications, pp. 51-52. <https://doi.org/10.4204/EPTCS.311>

*DOI:*

[10.4204/EPTCS.311](https://doi.org/10.4204/EPTCS.311)

*Publication date:*

2019

*Document Version*

Peer reviewed version

[Link to publication](#)

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# Intelligent Geometry Tools

James Davenport<sup>1</sup>, Jacques Fleuriot<sup>2</sup>, Pedro Quaresma<sup>3</sup>, Toms Recio<sup>4</sup>, and  
Dongming Wang<sup>5</sup>

<sup>1</sup> University of Bath, United Kingdom  
`masjhd@bath.ac.uk`

<sup>2</sup> University of Edinburgh, United Kingdom  
`jdf@inf.ed.ac.uk`

<sup>3</sup> CISUC/Department of Mathematics, University of Coimbra, Coimbra, Portugal  
`pedro@mat.uc.pt`

<sup>4</sup> University of Cantabria, Spain  
`tomas.recio@unican.es`

<sup>5</sup> Beihang University, China  
`Dongming.Wang@lip6.fr`

## Abstract

We propose building a community of “intelligent geometry” researchers, manifested by the creation of a living *Intelligent Geometry Book*, to introduce many more people to computer-supported reasoning.

On the one hand, participants at “Big Proof 2019” workshop<sup>1</sup> commented that students (mostly mathematics, but also computing) were not being introduced to formal methods and computer-supported reasoning at an early enough stage. On the other hand, for hundreds if not thousands<sup>2</sup> of years, geometry has been the tool of choice for introducing formal reasoning. Hence we propose that computer-supported reasoning in geometry is an ideal vehicle for exposing many more people to computer-supported reasoning than is currently the case.

The need for formal reasoning is not just a niche area in mathematics. The whole area of verified software relies on formal reasoning. Everyone who flies in or out of the UK has placed their lives in the hands of the air traffic controllers, supported by a computer system which has been formally verified, and the same is true of Line 14 (driverless) of the Paris Métro, or many railway systems. But the firms that develop such systems have an uphill struggle finding staff. They report that practically no recruit at the graduate level has been exposed to computer-supported reasoning.

Reuse of previous results is vital across science, but nowhere more than in mathematics. However, in practice re-use of *implementations of ideas* has proved much harder than re-use of *abstract ideas*. The same algorithm is implemented many times. Some of this re-implementation is due to real improvements (as we may provide a shorter or clearer proof of a theorem), but often it is due to “engineering” mismatches: different programming languages, data formats etc.

Therefore this project aims to build a community of researchers,<sup>3</sup> experts in the representation and management of geometric knowledge, and knowledge-based intelligent software for exploratory and educational purposes. By pooling the experiences of the participants over the fundamental issues to be addressed by any project in this area and making results open source/open access, the network will lay the ground for advanced research projects contributing to the European research agenda. The creation of this community will be demonstrated by the creation of a living *Intelligent Geometry Book*, the *i*GEOMETRYBOOK.

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<sup>1</sup><https://www.icms.org.uk/bigproof.php>.

<sup>2</sup>“There is no royal shortcut to Geometry”: Euclid c. 300 BC.

<sup>3</sup>The *Intelligent Geometry Community*, <http://staff.bath.ac.uk/masjhd/IGeom.html>

Hence our main challenge is to organise and harmonise the work of the participants and to integrate different techniques and tools developed by them, to facilitate collaborations within the network.

The *i*GEOMETRYBOOK will be an intelligent environment, collaborative, adaptive and adaptable, containing formally represented machine-checked geometric knowledge, historically analysed, with embedded tools for computation, deduction, and knowledge processing. It is envisaged that the knowledge contained in the *i*GEOMETRYBOOK will be created by the authors, with contributions from readers, using the embedded tools according to certain pre-designed mechanisms and remotely accessible and searchable with natural and visual languages interfaces.

Such a “superset of a book”, freely available in all computational platforms, adaptable, collaborative and adaptive to each and every user’s profiles, would bring together a whole new generation of mathematical tools with impact at all levels: exploratory research, applications on mathematics and education.

The need of information and communications technology (ICT) in a learning setting is well recognised, as said in *Mathematics Education in Europe: Common Challenges and National Policies* the use of ICT for teaching mathematics is prescribed or recommended in all European countries. The recommendations range from very specific instructions to more general guidelines [dEeC13, fE14, Iso10, Min11, Min10]. In particular, three of the aims in [fE14] are:

1. construct mathematical proofs;
2. make deductions and inferences and draw conclusions by using mathematical reasoning;
3. use technology such as calculators and computers effectively, and recognise when such use may be inappropriate.

It is our thesis that an appropriate interactive geometry tool can support, not only each aim above separately, but also the interplay of these aims.

In terms of the challenges of ARCADE, this should also respond to “How can we attract young people to our field?”.

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